Effects of RoHs and REACH regulations on firm-level production and export, and the role of global value chains : the cases of Malaysia and Vietnam

著者	Otsuki Tsunehiro, Honda Keiichiro, Michida Etsuyo, Nabeshima Kaoru, Ueki Yasushi
権利	Copyrights 日本貿易振興機構（ジェトロ）アジア経済研究所 / Institute of Developing Economies, Japan External Trade Organization (IDE-JETRO) http://www.ide.go.jp
journal or publication title	IDE Discussion Paper
volume	526
year	2015-04-01
URL	http://hdl.handle.net/2344/1483

INSTITUTE OF DEVELOPING ECONOMIES

IDE Discussion Papers are preliminary materials circulated to stimulate discussions and critical comments

IDE DISCUSSION PAPER No. 526

Effects of RoHS and REACH regulations on firm-level production and export, and the role of global value chains: The cases of Malaysia and Vietnam

Tsunehiro Otsuki[1], Keiichiro Honda[2], Etsuyo Michida[3], Kaoru Nabeshima[3] and Yasushi Ueki[4]

April 2015

Abstract This paper uses firm-level data to examine the impact of foreign chemical safety regulations such as RoHS and REACH on the production costs and export performance of firms in Malaysia and Vietnam. This paper also investigates the role of global value chains in enhancing the likelihood that a firm complies with RoHS and REACH. We find that in addition to the initial setup costs for compliance, EU RoHS (REACH) implementation imposes on firms additional variable production costs by requiring additional labor and capital expenditures of around 57% (73%) of variable costs. We also find that compliance with RoHS and REACH significantly increases the probability of export and that compliance with EU RoHS and REACH helps firms enter a greater variety of countries. Furthermore, firms participating in global value chains have higher compliance with RoHS and REACH regulations, regardless of whether the firm is directly exporting, when the firm operates in upstream or downstream industries of the countries' supply chain.

Keywords: trade; RoHS; REACH; cost function; market access; supply chain; Malaysia; Vietnam

JEL classification: F14, L15, O53

[1] Osaka School of International Public Policy, Osaka University,
[2] Faculty of Administration, Prefectural University of Kumamoto
[3] Institute of Developing Economies, JETRO
[4] Economic Research institute for ASEAN and East Asia

The Institute of Developing Economies (IDE) is a semigovernmental, nonpartisan, nonprofit research institute, founded in 1958. The Institute merged with the Japan External Trade Organization (JETRO) on July 1, 1998. The Institute conducts basic and comprehensive studies on economic and related affairs in all developing countries and regions, including Asia, the Middle East, Africa, Latin America, Oceania, and Eastern Europe.

INSTITUTE OF DEVELOPING ECONOMIES (IDE), JETRO
3-2-2, WAKABA, MIHAMA-KU, CHIBA-SHI
CHIBA 261-8545, JAPAN

Effects of RoHS and REACH regulations on firm-level production and export, and the role of global value chains: The cases of Malaysia and Vietnam

Tsunehiro Otsuki[1], Keiichiro Honda[2], Etsuyo Michida[3], Kaoru Nabeshima[3] and Yasushi Ueki[4]

Abstract: This paper uses firm-level data to examine the impact of foreign chemical safety regulations such as RoHS and REACH on the production costs and export performance of firms in Malaysia and Vietnam. This paper also investigates the role of global value chains in enhancing the likelihood that a firm complies with RoHS and REACH. We find that in addition to the initial setup costs for compliance, EU RoHS (REACH) implementation imposes on firms additional variable production costs by requiring additional labor and capital expenditures of around 57% (73%) of variable costs. We also find that compliance with RoHS and REACH significantly increases the probability of export and that compliance with EU RoHS and REACH helps firms enter a greater variety of countries. Furthermore, firms participating in global value chains have higher compliance with RoHS and REACH regulations, regardless of whether the firm is directly exporting, when the firm operates in upstream or downstream industries of the countries' supply chain.

[1] Osaka School of International Public Policy, Osaka University
1–31 Machikaneyama, Toyonaka, Osaka 560–0043, Japan.
Phone: +81–(0)6–6850–5619
Fax: +81–(0)6–6850–5619
[2] Faculty of Administration, Prefectural University of Kumamoto
[3] Institute of Developing Economies, Japan External Trade Organization
[4] Economic Research institute for ASEAN and East Asia
This paper is a revised version of IDE Discussion Papers 455 by Otsuki, Michida, Nabeshima, and Ueki (2014). It updates the estimates of the cost and export effects of RoHS and REACH regulations, and develops an analysis on the effects of global value chains on promotion of firm's compliance with those regulations.

1. Introduction

Countries adopt technical regulations, including safety and performance requirements, to ensure consumer safety and product quality. However, these regulations can constitute barriers to trade by imposing compliance costs on firms. A great deal of research has focused on the effects of regulations on producer performance in export and production in agricultural sectors. The majority of these studies have found that safety requirements tend to reduce exports, particularly in developing countries (see, for example, Otsuki et al. (2001)). Research on the effects of technical regulations on manufacturing exports, however, has been limited. Chen et al. (2008) used firm-level survey data to examine the effects of quality, safety standards, and labeling requirements on the export performance of manufacturing firms in 16 developing countries. Using the same dataset, Maskus et al. (2013) investigated the effects of technical regulations on firm-level production cost. The results of these studies generally imply that technical regulations can increase exports even though they increase the fixed and variable costs of production. While the dataset used in these studies covers a global set of developing countries, it does not include East Asian countries. In addition, the number of samples for individual countries is not large enough to conduct detailed analysis of a single country.

In this study, we use a new survey dataset to examine the effects of technical regulations on the performance of manufacturing firms in Malaysia and Vietnam with respect to both export and production. This study focuses on two sets of technical regulations targeting consumer and environmental safety in the EU: the Restriction of Hazardous Substances (RoHS) Directive and the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH). The EU RoHS Directive (Directive of the European Parliament and the Council on restriction of the use of certain hazardous substances in electrical and electronic equipment) took effect in 2006[1]. This directive restricts the amount of hazardous substances allowed in electronic and electrical (E&E) equipment. The EU REACH Regulation (Regulation of the European Parliament and

[1] The regulated substances are lead, mercury, cadmium, polybrominated biphenyls, and polybrominated diphenyl ethers.

Council concerning Registration, Evaluation, Authorisation and Restriction of Chemicals) entered into force in 2007 and regulates the use in products of chemical substances that cause serious concern for consumer health and the environment. Under REACH, if a product contains chemicals classified as SVHCs (Substances of Very High Concern) in excess of 0.1% by weight, firms are required to apply to the European Chemicals Agency for authorization.

The survey of firms in a wide range of industries in Malaysia and Vietnam conducted by Institute of Developing Economies allows us to investigate the role of the supply chain in promoting compliance with technical regulations in the export markets. East Asia is a region where international production networks are among the world's most sophisticated, as many studies have demonstrated (see, for example, Ando and Kimura (2005)). Compliance with technical regulations is likely to be encouraged when a downstream buyer makes requests for upstream supplies, and this supply chain management tends to work effectively for firms along the entire chain. For example, Koh et al. (2012) demonstrated the mechanism by which supply chain management encourages upstream suppliers to comply with safety requirements such as the EU's Waste Electrical and Electronic Equipment (WEEE) and RoHS.

Once the chemicals contained in a final product are regulated, the materials, parts and components that make up the final product must be redesigned, monitored, tested and shown to meet the stipulated chemical thresholds. Because parts and components suppliers are often located across borders, management of supply chains, value chains, and production networks takes place across firms, industries, and countries. To add to this complexity, product-related environmental regulations of chemicals impact various industries. Industries affected by REACH and RoHS include not only the chemical industry, but also the textiles, garment, wood products, plastic, rubber, machinery, and E&E industries, among others. Potentially affected industries are often located in developing countries, with those aiming at export to EU markets most affected.

Malaysia and Vietnam are rapidly industrializing countries in East Asia, and manufacturing exports have become an increasingly important engine of export-led growth for these countries. At the same time, these countries have faced increasing pressure from importing countries, particularly from developed countries and downstream buyers in the region, to meet safety and quality requirements. Although RoHS and REACH are only EU requirements, meeting those requirements can also signal superior safety and quality. Compliance with these standards may therefore help a firm enter non-EU markets. Our study aims to provide a complete picture of the effects of these regulations on the export performance and cost effectiveness of firms. Although production costs may increase, exports may do so as well. The empirical results will allow us to determine whether these requirements have a positive or negative net effect on firms by assessing which effect is dominant. This study also attempts to examine how global value chains promote compliance with those regulations. In particular, we are interested in whether non-exporting firms or upstream suppliers are also encouraged to comply with those regulations if they are a part of a global value chain.

In the production analysis, we evaluate an increase in variable costs due to RoHS and REACH compliance by using an estimation of a translog cost function according to Maskus et al. (2013). For the export analysis, we employ a probit model to examine the effect of RoHS and REACH on firm entry into the export market. We also employ an ordered probit model to examine the effects of the regulations on the number of export markets that firms enter. We also analyze the effect on average exports per market for firms by using a sample selection model. In both the cost and export analyses, we use instrumental variables for RoHS/REACH because compliance with these regulations may be an endogenous choice made simultaneously with production or export decisions. These analyses rely on instrumental variables for the RoHS and REACH variable in order to deal with a possible causality between a firm’s compliance with the regulations and their production and export decisions. Finally, we conduct an analysis of the effect of global value chains by using a probit estimation.

The remainder of this paper is organized as follows. Section 2 describes the backgrounds of Malaysia and Vietnam in terms of export performance and technical regulations. Section 3 explains the empirical approaches used in our analyses. Section 4 describes the data used for the empirical analyses. Section 5 presents and interprets the results of the cost and export analyses. Section 6 presents and interprets the results of the analysis of global value chains. Section 7 concludes the paper.

2. Background

2.1 Export performance of Malaysia and Vietnam

Exports of goods from Malaysia and Vietnam have grown rapidly during the past two decades, as shown in Figures 1 and 2. Malaysia has been a World Trade Organization (WTO) member since 1995, and Vietnam joined the WTO in 2007. Although Malaysia is a larger exporter than Vietnam, exports from both countries have been increasing rapidly. This is especially true for manufactured goods, where growth has been higher than that of exports of agricultural products. Figure 2 shows the positive impact of WTO membership on Vietnam's exports. In both figures, we can see the recovery from the global financial crisis and continued increases in exports. Our data show that 70% and 74% of the sampled firms in Malaysia and Vietnam, respectively, exported their products.

Vu et al. (2014) found rapid growth in the number of both domestic firms and multinational enterprises in Vietnam since 2000. Also, increased foreign direct investment and export has led to greater pressure on firms in Malaysia and Vietnam to comply with safety and quality regulations. After the introduction of the RoHS Directive, a growing number of countries have implemented their own versions of the RoHS standards. Vietnam introduced its version of RoHS in September 2011, and Malaysia also has a long history of regulating hazardous chemicals. Thus, we can infer that firms in Malaysia and Vietnam are quite aware of the importance of regulations on hazardous chemicals. Among respondent firms in Malaysian and Vietnam, 81% and 88%, respectively, had achieved compliance with RoHS by 2011; additionally, 70% in Malaysia and 87% in Vietnam had achieved compliance with REACH by 2011.

2.2 Related literature

Producers in developing countries face capacity constraints when complying with food safety and quality standards, which are typically imposed by developed countries. The significance of this is still unclear since firm-level quantitative studies on technical regulations are very limited, with research on developing countries being especially scarce.

On the other hand, country-level empirical studies that examine the effects of technical regulations on trade are relatively abundant, particularly in the food and agricultural sectors. Otsuki et al. (2001a) used a gravity model to show that the EU's aflatoxin standards discouraged African groundnut exports to the EU. A majority of studies of this kind have found negative effects of food safety standards (see, for example, Otsuki et al. (2001a), Wilson et al. (2003), Chen et al. (2008), Drogué and DeMaria (2012), and Winchester et al. (2012)). Honda (2012) is one of the few studies focusing on the manufacturing sector. He applied a gravity model to examine the effects of the EU's RoHS on exports to the EU market from EU and non-EU countries, finding that RoHS promoted intra-EU trade, but discouraged exports from non-EU countries. Unlike the other country-level studies, Xiong and Beghin (2013) attempted to isolate the positive demand-enhancing effect of food safety standards from the negative trade-cost effect using a more sophisticated gravity model.

In contrast, there have been relatively few firm-level studies. Wilson and Otsuki (2004) tried to use the World Bank's Technical Barriers to Trade (TBT) Survey Database to describe the benefits and difficulties that technical regulations bring to firms in developing countries. They showed that in 17 developing countries, approximately 70 percent of the surveyed firms across various industries claimed that the costs of testing and certification were likely to prevent them from exporting to major developed country markets. At the same time, approximately 80 percent of the surveyed firms responded that the assurance of product quality and safety was important for expanding their exports. The firms tried to comply with the technical regulations in various ways: by expanding their plants or equipment, by re-designing products, and by hiring labor for production and testing.

Using the above-mentioned database, Maskus et al. (2013) and Chen et al. (2008) developed methodological techniques for using firm-level data to analyze the effect of technical requisitions. Using a translog cost function, Maskus et al. (2013) conducted an estimation to see whether the presence of technical regulations would increase a firms' recurring variable production costs in addition to the initial setup costs. Chen et al. (2008) estimated firm-level export functions of intensive and extensive margins. They identified the factors that increase the amount of exports in a firm's total sales (intensive margin), and the number of export markets and products that are exported (extensive margin). Compliance with quality standards was found to increase not only the amount of exports, but also the number of export markets and products exported. In contrast, standard certification procedures were found to reduce the number of export markets and products exported.

Ragasa et al. (2011) also found support for the cost-increasing effect of technical regulations, noting that the US HACCP (Hazard Analysis and Critical Control Points) standard imposed significant additional production costs on firms in the seafood industry in the Philippines. Several studies support the demand-enhancing effect of compliance with technical regulations. Maertens and Swinnen (2008) pointed out that developed countries' stringent food safety standards do not always discourage developing country firms. Maertens and Swinnen (2009), and Maertens et al. (2011) demonstrated through a case study of Senegal's fresh and processed fruits and vegetables industry that compliance with food safety standards in developed countries can increase developing country exports to developed countries which appreciate high-quality products. Maertens et al. (2011) also pointed out the importance of the role of multinational enterprises in improving product quality and safety as leaders in the supply chain of food products. Fontagné et al. (2013) examined the effects of sanitary and phytosanitary standards on firm's probability to export (extensive margin), value of exports (intensive margin) and export prices using firm-level data for French agricultural and manufacturing firms.

3. Empirical strategy

3.1. Production analysis

Compliance with technical regulations imposes various costs on firms. Maskus et al. (2013) distinguished between the initial setup costs and the running or variable costs of complying with technical regulations. Although firms can be asked directly about their initial setup costs, they often cannot give an exact amount, especially if many years have passed since they first complied with the regulations. The additional running costs associated with regulations affect the consistency and amount of exports because these costs reduce profit margins. We therefore follow the approach of Maskus et al. (2013) for cost function estimation and use a translog cost function, which is flexible and can incorporate non-price variables such as factors for technical regulations.

Assume a short-run cost function

$$C = C(w, y; s, z), \qquad (1)$$

where w is a vector of factor prices, y is output, s indicates the stringency of the foreign standards, and z is a vector of other variables affecting firm-level costs. The firm minimizes variable costs wx, where x is a vector of variable inputs. The cost function is assumed to have some standard properties: non-decreasing on w and y, concave on w, and homogeneous of degree one with respect to w. This general cost function has a variable for technical regulations, s, as an argument because different technical regulations should affect the choice of inputs for producing a given output level. Maskus et al. (2013) used initial setup costs for technical regulations as a measure of the stringency of technical regulations, but we use a dummy variable indicating compliance with RoHS or REACH because of a lack of data about the setup costs associated with these regulations.

We assume that the cost function is weakly separable from the aggregator for material inputs and other inputs (separability). The separability assumption is necessary because we do not have data on the prices of materials and other inputs. We therefore specify equation (1) as the cost of producing net output, or value added, introducing only labor and capital as variable inputs, obtaining weak separability in this instance. This implies that the choice of the relative labor and capital inputs is independent of the material and intermediate input prices.[2] As a result, the cost function that reflects this technology is rewritten as

$$C(w,y;s,z)=(C^1(y,w^1;s,z),C^2(y,w^2;s,z)), \tag{2}$$

where $w^1 = \{w_L, w_K)$ and w^2 is the vector of prices for variable inputs other than labor and capital. For consistency with the linear homogeneity of C with respect to w, these subcomponents of the overall cost function are assumed to be homogeneous of degree one with respect to w^1 and w^2, as appropriate. Separating the cost function allows us to ensure that the elasticity of cost (value added) with respect to our technical regulation variables derived from the first component (C^1) is unaffected by the presence of the second component (C^2). This cost elasticity can be written as[3]

$$\sigma_s \equiv \frac{\partial C^1}{\partial s}\frac{s}{C^1} = \partial \ln C^1 / \partial \ln s\,. \tag{3}$$

Our specification of a short-run variable cost is a translog function. This translog function allows a flexible second-order approximation to a cost structure depending on output, input prices, and other factors, including technical regulations. The specification of costs for firm i is as follows:

---

[2] In our specific case, the separability condition is expressed as $\frac{\partial}{\partial w_j}\left(\frac{\partial C(w,y;s,z)/\partial w_L}{\partial C(w,y;s,z)/\partial w_K}\right)=0$, $j \neq L, K$ or $\frac{\partial}{\partial w_j}\left(\frac{\partial L(w,y;s,z)}{\partial K(w,y;s,z)}\right)=0$, $j \neq L, K$.

[3] When the technical regulation variables are of a binary type, we have $\sigma_s \equiv C^1(y,w^1;1,z)-C^1(y,w^1;0,z)$.

$$
\begin{aligned}
\ln \tilde{C}_i = {} & \beta_0 + \beta_y \ln y_i + \beta_L \ln w_{Li} + \beta_K \ln w_{Ki} + \frac{1}{2}\beta_{LL}(\ln w_{Li})^2 + \frac{1}{2}\beta_{KK}(\ln w_{Ki})^2 \\
& + \frac{1}{2}\beta_{yy}(\ln y_i)^2 + \beta_{LK} \ln w_{Li} \ln w_{Ki} + \beta_{Ly} \ln w_{Li} \ln y_i + \beta_{Ky} \ln w_{Ki} \ln y_i + \beta_s s_i \\
& + \beta_{Ls} s_i \ln w_{Li} + \beta_{Ks} s_i \ln w_{Ki} + \beta_{ys} s_i \ln y_i + \frac{1}{2}\beta_{ss} s_i^{\,2} \\
& + \sum_{n=1}^{N} \beta_{zn} z_n + \sum_{c=1}^{C} \beta_{zc} z_c + \varepsilon_i .
\end{aligned}
\tag{4}
$$

Here, $\tilde{C}$ denotes value added (cost of labor and capital, referred to as production costs hereinafter), w_L denotes the wage rate, w_K denotes the unit price of capital, y denotes sales as a measure of output, and s denotes the firm-specific measure of technical regulations. The variables z_n and z_c denote industry-specific and country-specific factors, respectively, that affect firm costs. We use industry and country dummies to control for these effects.

This translog cost function is estimated jointly with an equation for the share of labor cost in production costs:

$$
S_{Li} = \beta_L + \beta_{LL} \ln w_{Li} + \beta_{LK} \ln w_{Ki} + \beta_{Ly} \ln y_i + \beta_{Ls} s_i + \mu_i . \tag{5}
$$

We eliminate the capital-share equation from the estimation because it is fully determined by the constraints below. Note that in writing these equations, we have imposed the required symmetry in cross-variable coefficients. Furthermore, the linear homogeneity condition imposes the following constraints:

$$
\begin{aligned}
& \beta_L + \beta_K = 1 \\
& \beta_{KK} + \beta_{LK} = 0 \\
& \beta_{LL} + \beta_{LK} = 0 \\
& \beta_{Ly} + \beta_{Ky} = 0 \\
& \beta_{Ls} + \beta_{Ks} = 0
\end{aligned}
\tag{6}
$$

Equations (4) and (5) are estimated jointly in an iterative three-stage least squares procedure (I3SLS), subject to the constraints in the system of equations (6). In addition to consistency and asymptotic efficiency, the I3SLS procedure guarantees identical translog cost parameters irrespective of which share equation is dropped (Berndt and Wood, 1975). The parameters for the dropped equation can be recovered by using the symmetry condition and the conditions in the system of equations (6).

From equation (4), we can calculate the direct elasticity of production costs with respect to foreign standards as $\sigma_s^d = \beta_s + \beta_{ss} \ln s_i$, which varies with the level of technical regulations. We are also interested in the impact of the standards on factor demands. The coefficient β_{Ls} in the system of equations (6) measures the bias toward labor use (impact on labor share) from an increase in foreign technical regulations ($\varphi_{Ls} \equiv \partial S_L / \partial \ln s = \beta_{Ls}$), and the bias toward capital use, ($\varphi_{Ks} \equiv \partial S_K / \partial \ln s = \beta_{Ks}$). The need to satisfy these technical regulations could effectively generate an overall increase in costs, along with a bias in factor use toward either labor or capital.

In addition to the direct elasticity of cost, we can calculate the total elasticity of cost with respect to a change in the stringency of technical regulations while accounting for impacts on factor use:

$$\sigma_S \equiv \partial \ln \tilde{C} / \partial \ln s = \beta_s + \beta_{ss} \ln s_i + \beta_{Ls} \ln w_{Li} + \beta_{Ks} \ln w_{Ki} + \beta_{ys} \ln y_i . \qquad (7)$$

We use the binary variable as an instrument for technical regulations due to its possible endogeneity (a firm with greater productivity or cost efficiency is more willing to or capable of complying with technical regulations). The instrumental variables include dummy variables for a request to implement measures regarding chemical substances in the firm’s products, the status of acquisition of either ISO 9001 or ISO 14001 certification, and the experience of difficulty in procuring inputs. The question for the first instrumental variable is “Have you ever needed or been asked to implement measures regarding chemical substances in your products? Examples include the testing of products, changing inputs to reduce or eliminate certain chemicals, and providing information about chemicals contained in your products since 2000” The question for the second variable is “Do you have any internationally recognized certificates such as ISO and, if so, which ones?” The question for the last variable is “Have you ever experienced difficulty in procuring inputs in order to meet chemical regulations/private requirements?” The criteria for selecting these instruments will be discussed in the subsequent subsection.

3.2. Export analysis

We now move to the estimation approach for the effect of technical regulations on various measures of export performance of firms, namely the firm’s entry into export markets, the number of export markets, and the export amount.

We begin by considering the firm’s entry into export markets. A binary variable is given the value one when the firm exports to at least one foreign country and zero otherwise. A probit model is used to estimate the effect of technical regulations, *s*, along with other regressors. We then focus on the number of export markets as a measure of export diversification (we refer to this as the extensive margin in keeping with the literature). This model allows us to examine whether meeting RoHS or REACH will offer opportunities for the firm to export to a greater variety of markets. Since we are dealing with an ordered dependent variable, an ordered probit model is used for this estimation. We focus on the amount of a firm’s exports as a measure of the magnitude of exports instead of entry or count of markets in order to capture the intensity of exports. We refer to this as the intensive margin. Since the ordered probit estimation addresses market diversification, a complementary measure of export intensity would be (the logarithm of) the average export amount per market instead of the total export amount. The total amount reflects both the extensive and intensive margins. It is also common in the literature to estimate the intensive margin model using the Heckman sample selection model while taking the sample selection into account. This sample selection is represented by the above probit model corresponding to the extensive margin, as is typical.

We also admit the possibility of endogeneity of the RoHS and REACH variables in the export analysis because exporting firms are expected to face these regulations and are thus more inclined to comply with them. Thus, these probit models for export regime are estimated using the instrumental variable probit (IV probit) model. The same instrumental variables as the production analysis are used. They are selected based on the major tests to qualify instrumental variables, namely, Cragg-Donald statistic for weak instrumental variable, the Hansen J statistic for overidentifying restriction, the Kleibergen-Paap rank Lagrange multiplier (LM) statistic for underidentification, and the Wu-Hausman statistic for exogeneity of instruments. These tests are conducted based on the two-stage least squares (2SLS) as some of the tests are not available for the IV probit model. It is not guaranteed that the instrumental variables selected based on the export regime regression will apply to the regression for the number of the export markets, for the export amount, or for the cost function, but we use the same set of instrumental variables throughout the production and export analysis in order to maintain the integrity of the analyses. Fortunately, these instruments satisfy these tests for most of the regression models.

3.3. Analysis of global value chains

The role of global value chains in promoting compliance with RoHS\REACH regulations is analyzed using a probit regression. We are particularly interested in whether the positive effect of global value chains remains even though the firm is a non-exporter or upstream supplier who is unlikely to be subject to a direct request from buyers in importing countries to comply with those regulations. We can therefore examine the indirect effect of quality and safety management through the supply chain. This kind of analysis is best executed by introducing an interaction term for the exporter or upstream (or downstream) dummies with a dummy for a global value chain.

4. Data

4.1. Survey in Malaysia

The data for Malaysia were collected in the Malaysian state of Penang from 2012 to 2013[4]. Penang was chosen because of its large agglomeration of industries, with many of the targeted firms located in the area. The project was also endorsed by the government of Penang, as the state government recognized the importance of the issue. The actual survey was conducted by PE Research of Malaysia.

Our questionnaire comprised four sections: 1) basic information, 2) input procurement and certificates, 3) chemical management, and 4) export status. Surveyed firms were sampled from those firms recorded in the Penang Industrial Census of 2011, which collected data on 2,116 firms, of which 1,898 were manufacturers and 218 were service firms. Beginning in November, 2012, questionnaires were sent to 732 of these firms, and the questionnaires were followed up with phone calls. We received replies from 374 firms, giving us a response rate of approximately 51%[5]. From the manufacturing industries 346 firms were chosen, while 23 firms were taken from the service sectors. We targeted those sectors for which the management of chemicals contained in products was likely to be necessary. The share of small and medium enterprises, here defined as fewer than 200 employees, was 83.4%, or 308 of the chosen firms. Among the chosen firms, 72.6% (268) were 100% locally owned, and 18.7% (69) firms were 100% foreign-owned firms; the remaining 32 firms were joint ventures between local and foreign owners.

4.2. Survey in Vietnam

The data for Vietnam were collected from throughout the entire country in 2011 and 2012. In Vietnam the survey was conducted by the Vietnamese Chamber of Commerce and Industry. The population consisted of firms in operation according to the General

[4] The data were collected under the IDE-JETRO research project “Impact of product-related environmental regulations on international trade and technological spillovers through supply chain in Asia”.

[5] The authors wish to thank the local governments, Invest Penang and Penang industrial associations, Federation of Malaysian manufacturers (FMM) in the Northern Region and the association of companies in the free zones (FREPENCA) for endorsing our research project and also those firms who kindly filled out our form.

Department of Taxation. Target firms included both those in manufacturing and those in commerce sectors where the management of chemicals in products is an issue. Of the 15,358 firms in the population, survey forms were sent to 11,978 firms across all provinces. A response rate of 8.8% (1055 firms) was obtained. Domestic firms account for 67.4% of respondents (710 firms), foreign direct investment (FDI) firms for 31.8% (335 firms), and state-owned enterprises for 0.9% (9 firms). Among respondents, 57.6% were small and medium enterprises, defined here as those with fewer than 300 employees.

4.3 Descriptive statistics

The survey focuses on a variety of industries in Malaysia and Vietnam. The industries studied and the count of firms can be found in Table 1. Note that the number of samples will be limited to those that are used in the subsequent empirical analysis hereinafter. Table 2 shows descriptive statistics for the variables used in the cost and export analyses. First, we describe the variables used in the cost analysis. The average value added cost and sales are greater in Malaysia than in Vietnam. In Malaysia, we find that the wage rate and unit price of capital are higher. We define global value chains as networks of firms that procure inputs from various countries and sell the resulting products globally, such as automotive products, electronics, and garments. Firms were asked whether they supplied their main products to global supply chains. In Malaysia, more firms were integrated into global value chains. The number of firms complying with RoHS and REACH is also far greater in Malaysia. The survey also asked firms whether they were able to meet EU RoHS and REACH standards along with other regulations and requirements.[6]

We next describe the variables used in the export analysis that were not used in the cost analysis. The fraction of firms exporting to any foreign country is quite similar between Malaysia (69%) and Vietnam (62%). However, the fraction of firms exporting to EU countries is greater in Vietnam (33%) than in Malaysia (25%). The average export

[6] We assume that non-response implies non-compliance so as to conserve a loss of samples due to missing data.

amount per market in Malaysia is slightly more than twice that in Vietnam. The number of years since the firm was established is greater in Malaysia, perhaps reflecting the country's earlier economic growth and industrialization. The average number of employees is smaller for Malaysia perhaps reflecting its tendency for greater capital intensity. The fraction of multinational enterprises is greater in Vietnam. The number of years since the firm's main product was first produced and the type of company's business registration form are used for the exclusion restriction in the Heckman sample selection model.

5. Results

5.1. Production analysis

The cost function was run jointly with the labor share equation under alternative specifications. Instrumental variables were used for RoHS and REACH to mitigate the effects of endogeneity. The predicted value of RoHS (or REACH) from the ordinary least squares (known as the linear probability model) of the reduced-form regression (a model with instruments and exogenous variables as regressors is used in place of the original RoHS/REACH dummy. The parameter estimates with respect to the translog model are presented in Table 3. Robust standard errors are reported in parentheses. The equation includes industry and country fixed effects. The fit of each model is good based on adjusted R-squared coefficients. We examine local concavity in input prices and positivity of input shares for the translog model according to procedures as described by Berndt and Wood (1975). Our translog cost function is found to satisfy these conditions.

The results are presented in Table 3. The coefficients for both the RoHS and REACH variables are positive and significant. This indicates that the direct effect of RoHS and REACH is significant and indicates increased variable production costs due to compliance. According to the translog model, cost increases due to RoHS and REACH are 57.3% and 73.1% of total (labor and capital) costs, respectively.

When we consider that our estimate concerns only labor and capital costs, we find that additional cost variables may be necessary. These could include cost of raw materials, intermediate inputs and other costs. Firms have also already incurred the initial setup costs for compliance with these regulations. We therefore see that the costs associated with RoHS and REACH compliance appear to be nontrivial.

The effect of participating in a global value chain is not evident because the coefficients for the global value chains dummy are insignificant in the case of both RoHS and REACH. Firms are unlikely to enjoy a cost-saving effect from participation in global value chains.

5.2. Export analysis

In the export analysis, we focused on the firm's entry to export markets, the number of export markets, and the export amount. The results for RoHS and REACH are presented in Tables 4 and 5, respectively. The first and second columns of these tables, respectively, show the results of the 2SLS and probit regressions used to examine whether compliance with RoHS and REACH improves the firm's ability to access foreign markets generally. For the respective regressions, the third and fourth columns show whether compliance improves the firm's ability to access EU markets specifically. The results indicate that both RoHS and REACH compliance increases the probability of entering both EU markets and foreign markets in general.

The fifth column of these tables shows the results of the ordered probit estimation. We find that compliance with RoHS and REACH significantly increases the number of export markets. We can therefore conclude that compliance with RoHS and REACH helps firms to access a greater variety of countries. Thus, compliance with RoHS and REACH seems to signal the safety and quality of a firm's products and to help the products gain acceptance in other markets.

The sixth and seventh columns of these tables show the results of a Heckman sample selection estimation examining the effect of compliance with RoHS and REACH on the average amount exported per market as a measure of the intensive margin.[7] The results indicate that the (log) average export amount per export market does not significantly increase with compliance with RoHS or REACH. Thus, the major benefit of RoHS and REACH compliance is the diversification of export markets rather than an increase in export amount.

There is no strong evidence that multinational enterprises or firms participating in global value chains tend to exhibit a greater propensity to export, diversity in export markets or scale of export.

We also examine robustness of the full-sample results of the export analysis using the sub-sample of firms in the industries facing RoHS and REACH regulations. The results are largely the same as those of the full-sample estimation. The results are omitted in order to save space.

Overall, compliance with RoHS and REACH provides firms with better access to export markets but the advantage of compliance with RoHS is likely to be found in accessing the EU market. This may indicate that EU REACH is more universal than EU RoHS. However, this finding seems to contradict our observation that RoHS-type regulations are more widely adopted than REACH-type regulations. Thus, detailed investigation about the dissimilarity of these regulations across countries would be necessary.

5.3. Results of the global value chain analysis

Finally, we analyze how global value chains might promote firms' compliance with RoHS and REACH in consideration of the different status of firms in terms of export regime and their position in the supply chains. In Table 6, industries are categorized as upstream or downstream according to their typical position in the supply chain. Tables 7

[7] It should be noted that the inverse mills ratios are insignificant in both tables, implying that sample selection is not severe enough to cause the biased coefficient estimators.

and 8 respectively show the result of probit regression for the effects of global value chains on RoHS and REACH compliance. Four different specifications are examined where dummy variables for Malaysia, export status, and participation in global value chains are included in all models. The first model has no additional regressors. The remaining models include either or both of the following interaction terms: global value chain dummy*export dummy and global value chain dummy*upstream industry dummy. Positive and significant effect of export regime and global value chain is observed in all models in the RoHS and REACH cases. This implies that exporting firms and firms participating global value chains tend to comply with RoHS and REACH. We also find that firms in Malaysia are more likely to comply with these regulations than those in Vietnam.

The models with interaction terms, on the other hand, indicate that none of the interaction terms is significant. This implies that export status or position in the supply chain does not affect the way that global value chains encourage firms to comply with RoHS and REACH. This means that global value chains encourage even non-exporting firms and upstream suppliers to make efforts to comply with RoHS and REACH. Thus, the result suggests that supply chain management works effectively to ensure that participating firms satisfy the requirements of RoHS and REACH no matter where they are in the supply chain ladder.

6. Conclusions

This study used firm-level data to examine the impact of foreign chemical safety regulations such as RoHS and REACH on the production costs and export performance of firms in Malaysia and Vietnam. We found that in addition to the initial setup costs for compliance, EU RoHS and REACH implementation causes firms to incur additional variable production costs by requiring additional labor and capital expenditures of around 57% and 73% of the variable costs, respectively. We also found that compliance with RoHS and REACH significantly increases the probability of export. A further finding was that compliance with EU RoHS and REACH helps firms enter a greater variety of countries.

On the other hand, it was found that RoHS and REACH compliance has no effect on the average export amount per market and that global value chains promote firms to comply with RoHS and REACH regulations irrespective of their export status or position in supply chain.

In summary, RoHS and REACH impose on firms both initial setup costs and additional variable production costs. Compliance with these regulations can, however, reward firms with improved access to a greater number of export markets. The benefits of compliance may therefore exceed the additional costs although a direct comparison is not pursued in this paper due to the difference in the nature of the performance measures. Further investigation that focuses on differences in RoHS- and REACH-type chemical safety regulations across countries, in particular, between the EU and non-EU countries, is necessary to make useful recommendations for both exporting firms and regulating countries so as to avoid technical regulations that constitute unnecessary barriers to trade. Effort to harmonize regulations globally may increase economic benefits if they aim to achieve the same public goals and if cross-country differences in regulations are not significant.

References

Ando, M. and F. Kimura (2005). "The Formation of International Production and Distribution Networks in East Asia." in T. Ito and A. K. Rose (eds.), International Trade in East Asia, NBER-East Asia Seminar on Economics, Vol.14, University of Chicago Press, pp. 177-213.

Berndt, E. R. and D. O. Wood (1975). "Technology, Prices, and the Derived Demand for Energy." *Review of Economics and Statistics* 57, pp. 259-68.

Burnquist, M. J. P. Souza and R. N. Faria (2012). "The Impact of Regulatory Heterogeneity on Agri-Food Trade," *The World Economy*, Vol.35, No.8, pp.973-993.

Chen, C., J. Yang and C. Findlay (2008). "Measuring the Effect of Food Safety Standards on China's Agricultural Exports," *Review of World Economics*, Vol.144, No.1, pp.83-106.

Chen, M., T. Otsuki and J. Wilson (2008). "Standards and Export Decisions: Firm-Level Evidence from Developing Countries," *Journal of International Trade and Economic Development,* Vol.17, No.4, pp.501-523.

Drogué, S. and F. DeMaria (2012). "Pesticides residues and trade: the apple of discord?" *Food Policy*, Vol.37, No.6, pp.641-649.

Fontagné, L., G. Orefice, R. Piermartini and N. Rocha (2013). "Product Standards and Margins of Trade: Firm Level Evidence," *CESifo Working Paper* No. 4169, Center for Economic Studies and Ifo Institute, München, pp.1-28.

Honda, K. (2012). "The Effect of EU Environmental Regulation on International Trade: Restriction of Hazardous Substances as a Trade Barrier," *IDA Discussion Papers*, No.341.

Koh, S. C. L., A. Gunasekaran, and C. S. Tseng (2012). "Cross-tier ripple and indirect effects of directives WEEE and RoHS on greening a supply chain." International Journal of Production Economics, Vol. 140, No. 1, pp. 305–317.

Maertens, M. and J. F. M. Swinnen (2008). "Standards as Barriers and Catalysts for Trade, Growth and Poverty Reduction," *Journal of International Agricultural Trade and Development*, Vol.4, No.1, pp.47-62.

Maertens, M. and J. F. M. Swinnen (2009). "Trade, Standards, and Poverty: Evidence from Senegal," *World Development*, Vol.37, No.1, pp.161-178.

Maertens, M., L. Colen and J. F. M. Swinnen (2011). “Globalisation and poverty in Senegal: A Worst Case Scenario?”*European Review of Agricultural Economics*, Vol.38, No.1, pp.31-54.

Maskus, K. E., T. Otsuki and J. S.Wilson (2013). “Do Foreign Product Standards Matter? Impacts on Costs for Developing Country Exporters,” *Asia Pacific Journal of Accounting and Economics*, Vol.20, No.1, pp.37-57.

Otsuki, T., J. S. Wilson and M. Sewadeh (2001a). “What Price Precaution? European Harmonization of Afflation Regulations and African Groundnut Exports,” *European Review of Agricultural Economics*, Vol.28, No.2, pp.263-283.

Otsuki, T., J. S. Wilson and M. Sewadeh (2001b). “Saving Two in A Billion: Quantifying the Trade Effect of European food Safety Standards on African Exports,” *Food Policy*, Vol.26, No.5, pp.495-514.

Ragasa, C., S. Thornsbury and S. Joshi (2011). “Are Food Certification Costs Misestimated? Exporter-Perspective on the European Standard,” *Journal of Agricultural Economics*, Vol.62, No.3, pp.669-689.

Tien, M. V., H. Yamada and T. Otsuki (2014). “The rise and fall of multinational enterprises in Vietnam:survival analysis using census data during 2000-2011,” *OSIPP Discussion Paper*, Osaka University, DP-2014-E-001.

Wilson, J. S. and T. Otsuki (2003). “Food Safety and Trade: Winners and Losers in a Non-Harmonized World,” *Journal of Economic Integration*, Vol.18, No.2, pp.266-287.

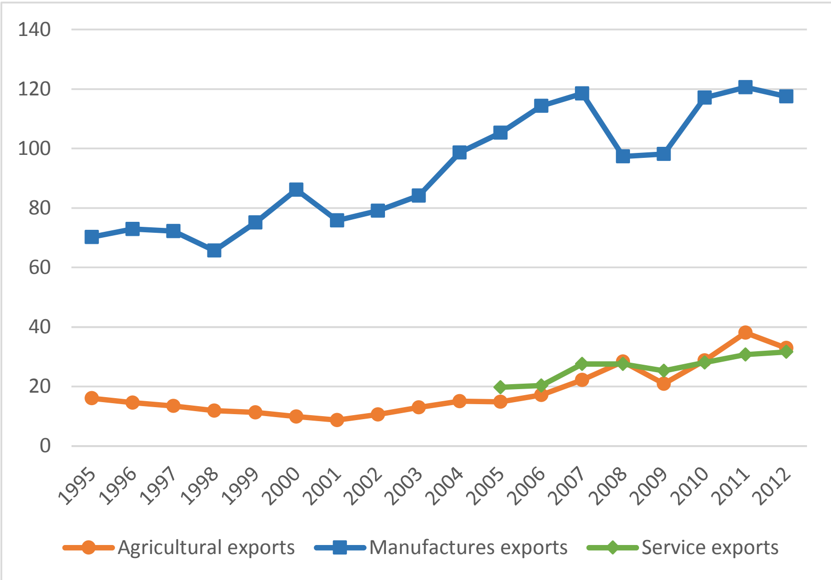
Wilson, J. S. and T. Otsuki (2004). “Standards and Technical Regulations and Firms in Developing Countries: New Evidence from A World Bank Technical Barriers to Trade Survey,” *unpublished*, The World Bank, Washington, D.C.

Wilson, J. S., T. Otsuki and B. Majumdar (2003). “Balancing Food Safety and Risk: Do Drug Residue Limits Affect International Trade in Beef?” *Journal of International Trade and Economic Development*, Vol.12, No.4, pp.377-402.

Winchester, N., M. L. Rau, C. Goetz, B. Larue, T. Otsuki, K. Shutes, C. Wieck, H. L. Burnquist, M. J. P. Souza and R. N. Faria (2012). “The Impact of Regulatory Heterogeneity on Agri-Food Trade,” *The World Economy*, Vol.35, No.8, pp.973-993.

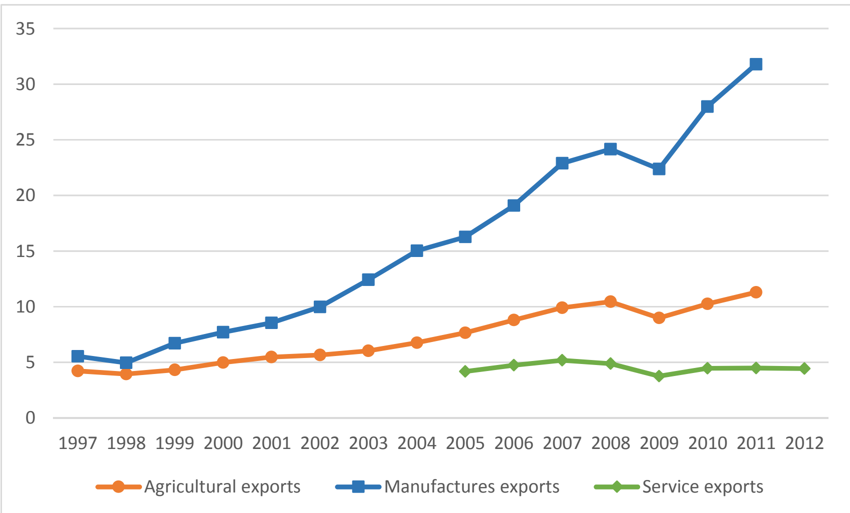
Xiong, B. and J. Beghin (2013). “Disentangling Demand-Enhancing And Trade-Cost Effects of Maximum Residue Regulations”, *Working Paper* 13-WP 544, Iowa State University, Department of Economics, pp.1-35.

Figure 1. Malaysia's Exports (in billions of USD)



Source: Author’s calculations from World Development Indicators data

Figure 2. Vietnam's Exports (in billions of USD)



Source: Author’s calculations from World Development Indicators data

Table 1. Industries and number of firms included in the analysis

	Total	Malaysia	Vietnam	RoHS	REACH
Food products	48	21	27		
Beverages	6	4	2		
Textiles	24	7	17	x	x
Wearing apparel	99	6	93	x	x
Leather and related products	8	0	8	x	x
Wood and products of wood and cork, except furniture,	44	4	40	x	x
Paper and paper products	9	7	2	x	x
Printing and reproduction of recorded media	9	7	2	x	x
Coke and refined petroleum products	2	1	1	x	x
Chemicals and chemical products	17	13	4	x	x
Basic pharmaceutical products and pharmaceutical preparation	2	1	1	x	x
Rubber and plastics products	49	31	18	x	x
Other non-metallic mineral products	7	1	6	x	x
Basic metals	24	20	4	x	x
Fabricated metal products, except machinery and equipment	43	37	6	x	x
Computer, electronic and optical products	23	17	6	x	x
Electrical equipment	16	10	6	x	x
Machinery equipment	19	15	4	x	x
Motor vehicles, trailers and semi-trailers	5	2	3		x
Other transport equipment	6	4	2		x
Furniture	19	4	15	x	x
Other manufacturing	59	8	51	x	x
Wholesale and retail trade, and repair and installation of machinery and equipment including motor vehicles and motor-cycles	11	3	8		
Others	46	0	46		

Source: Malaysia and Vietnam firm surveys. These counts are for the responses used in the empirical analyses.

Table 2. Descriptive statistics of the variables used in the empirical analysis

	Malaysia			Vietnam		
Variable	Obs.	Mean	Std. Dev.	Obs.	Mean	Std. Dev.
Cost analysis						
Value added cost (million USD)	220	15.9	36.5	391	3.19	5.20
Sales (million USD)	220	23.7	50.0	391	5.21	7.60
Wage rate (USD)	220	7129	8180	391	3153	11455
Unit capital price (USD)	220	3.389	5.466	391	1.444	2.726
Participation in global value chain	220	0.518	0.501	391	0.203	0.403
RoHS compliance	220	0.341	0.475	391	0.092	0.289
REACH compliance	220	0.241	0.429	391	0.092	0.289
Export analysis						
Entry to export market	220	0.686	0.465	349	0.619	0.486
Entry to EU market	220	0.250	0.434	349	0.327	0.470
Number of export markets	220	2.700	2.609	349	1.613	2.031
Average export per export market (million USD)	154	6.47	18.5	175	2.70	4.58
Number of years since the firm was established	220	13.832	2.173	175	13.639	1.743
Number of employees	220	19.568	12.747	349	10.444	9.539
Multinational enterprise	220	151.1	287.0	349	504.2	1115.2
Number of years since the main product was first produced	220	0.218	0.414	349	0.292	0.455
Financial stake	219	1.602	1.158	321	1.666	0.940

Source: The authors' calculations from Malaysia and Vietnam firm survey data.

Table 3. Cost function estimation

	RoHS	REACH
Variables	translog	translog
Constant	4.979***	5.024***
	(1.839)	(1.837)
$\log y$	0.419*	0.414*
	(0.251)	(0.251)
$(\log y)^2$	0.0280	0.0281
	(0.0171)	(0.0171)
$\log w_L$	-0.0192	-0.0190
	(0.0603)	(0.0603)
$\log w_K$	1.019***	1.019***
	(0.0603)	(0.0603)
$(\log w_L)^2$	0.0663***	0.0663***
	(0.00260)	(0.00260)
$(\log w_K)^2$	0.0663***	0.0663***
	(0.00260)	(0.00260)
$\log w_L \log w_K$	-0.0663***	-0.0663***
	(0.00260)	(0.00260)
$\log w_L \log y$	-0.0155***	-0.0156***
	(0.00361)	(0.00361)
$\log w_K \log y$	0.0155***	0.0156***
	(0.00361)	(0.00361)
s (= RoHS	0.574**	0.731**
or REACH)	(0.273)	(0.311)
Global value	-0.0460	-0.0669
chain	(0.102)	(0.104)
Malaysia	-0.529***	-0.486***
dummy	(0.116)	(0.112)
Observations	569	569
R-squared	0.796	0.797

Robust standard errors are in parentheses *** p<0.01, ** p<0.05, * p<0.1. The instrumental variables for 2SLS include dummy variables for the experience of a request to take chemical measures about chemical substances, the status of acquisition of either ISO 9001 or ISO 14001, and experience of a difficulty to procure inputs.

Table 4. Results of export regressions for RoHS

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Export entry	Export entry	Export entry to EU	Export entry to EU	Number of export markets	log export amount	
Variables	2SLS	IV probit	2SLS	IV probit	Ordered probit	Heckman 2nd stage	Heckman 1st stage
RoHS	0.531***	0.382***	0.564***	0.504***	1.725***	0.263	1.753***
	(0.135)	(0.0929)	(0.132)	(0.0797)	(0.334)	(0.955)	(0.531)
Firm age	0.00209	0.000387	0.00530**	0.00426**	0.00737	0.0149	0.0399**
	(0.00213)	(0.00192)	(0.00209)	(0.00197)	(0.00514)	(0.0130)	(0.0186)
wage	2.79e-06*	7.21e-06**	2.72e-06**	3.04e-06	4.90e-06**	1.70e-05	3.31e-05**
	(1.67e-06)	(3.37e-06)	(1.15e-06)	(3.23e-06)	(2.49e-06)	(1.17e-05)	(1.61e-05)
employment	8.90e-05***	0.000714***	0.000106***	9.58e-05***	0.000337***	0.000331*	0.00338***
	(3.20e-05)	(0.000139)	(3.25e-05)	(3.48e-05)	(8.68e-05)	(0.000189)	(0.000660)
MNE	0.161***	0.0765	-0.0134	-0.00985	0.192	0.666**	-0.658
	(0.0502)	(0.0499)	(0.0591)	(0.0424)	(0.124)	(0.328)	(0.877)
Global value	0.0798	0.0307	0.0135	-8.95e-05	0.259**	-0.0515	0.119
chain	(0.0568)	(0.0509)	(0.0594)	(0.0482)	(0.131)	(0.344)	(0.221)
Malaysia dummy	-0.0910	-0.0511	-0.278***	-0.243***	0.0567	0.260	-0.215
	(0.0624)	(0.0552)	(0.0538)	(0.0555)	(0.143)	(0.399)	(0.257)
Years of production							-0.0460**
							(0.0188)
Ownership (100% domestic							-1.119
firm)							(0.800)
Ownership (partial foreign							-0.131
ownership)							(0.447)
Constant					4.592***	14.93***	0.102
					(0.445)	(0.801)	(0.790)
Inverse mills ratio						-2.354***	
						(0.524)	
Uncentered R2	0.154		0.077				
Cragg-Donald statistics for weak instrument	31.264***		20.461***				
Hansen J statistics for overidentifying restriction	3.982		4.494				
Kleibergen-Paap rank LM for underidentification	74.013***		53.081***				
Wu-Hausman statistics for exogeneity of instruments	21.933***		16.096***				
Observations	463	441	463	443	463	444	444

Robust standard errors are in parentheses *** p<0.01, ** p<0.05, * p<0.1. See the footnote of Table 3 for the selection of the instrumental variables.

Table 5. Results of export regressions for REACH

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Export entry	Export entry	Export entry to EU	Export entry to EU	Number of export markets	log export amount	
Variables	2SLS	IV probit	2SLS	IV probit	Ordered probit	Heckman 2nd stage	Heckman 1st stage
REACH	0.696***	0.522***	0.733***	0.613***	2.250***	0.242	2.319***
	(0.183)	(0.118)	(0.193)	(0.0905)	(0.448)	(1.276)	(0.713)
Firm age	-0.000301	-0.00125	0.00280	0.00171	-0.000364	0.0143	0.0315*
	(0.00237)	(0.00201)	(0.00250)	(0.00207)	(0.00565)	(0.0142)	(0.0186)
wage	3.28e-06	7.42e-06**	3.23e-06	3.14e-06	6.51e-06**	1.71e-05	3.48e-05**
	(2.08e-06)	(3.30e-06)	(2.20e-06)	(2.95e-06)	(2.56e-06)	(1.19e-05)	(1.61e-05)
employment	8.73e-05***	0.000707***	0.000104***	8.30e-05**	0.000331***	0.000331*	0.00339***
	(3.21e-05)	(0.000143)	(3.38e-05)	(3.36e-05)	(8.77e-05)	(0.000189)	(0.000659)
MNE	0.150***	0.0688	-0.0239	-0.0161	0.158	0.665**	-0.686
	(0.0531)	(0.0504)	(0.0560)	(0.0410)	(0.126)	(0.330)	(0.877)
Global value	0.0589	0.00645	-0.00758	-0.0212	0.192	-0.0446	0.0460
chain	(0.0601)	(0.0534)	(0.0634)	(0.0482)	(0.138)	(0.363)	(0.233)
Malaysia dummy	-0.0590	-0.0317	-0.244***	-0.193***	0.161	0.281	-0.107
	(0.0602)	(0.0537)	(0.0635)	(0.0544)	(0.140)	(0.385)	(0.249)
Years of production							-0.0457**
							(0.0188)
Ownership (100% domestic							-1.107
firm)							(0.799)
Ownership (partial foreign							-0.125
ownership)							(0.447)
Constant						14.95***	0.195
						(0.788)	(0.790)
Inverse mills ratio						-2.359***	
						(0.524)	
Uncentered R2	0.112		-0.021				
Cragg-Donald statistics for weak instrument	20.461***		20.461***				
Hansen J statistics for overidentifying restriction	4.494		4.319				
Kleibergen-Paap rank LM for underidentification	53.081***		53.081***				
Wu-Hausman statistics for exogeneity of instruments	18.273***		17.128***				
Observations	463	441	463	443	463	444	444

Robust standard errors are in parentheses *** p<0.01, ** p<0.05, * p<0.1. See the footnote of Table 3 for the selection of the instrumental variables.

Table 6. Categorization of upstream/downstream industries (by production processes)

	Number of firms	RoHS	REACH
UPSTREAM INDUSTRIES			
Leather and related products	8	x	x
Wood and products of wood and cork, except furniture	44	x	x
Paper and paper products	9	x	x
Chemicals and chemical products	17	x	x
Basic metals	24	x	x
Wholesale and retail trade, and repair and installation of machinery and equipment including motor vehicles and motor-cycles	11		
DOWNSTREAM INDUSTRIES			
Food products	48		
Beverages	6		
Textiles	24	x	x
Wearing apparel	99	x	x
Printing and reproduction of recorded media	9	x	x
Coke and refined petroleum products	2	x	x
Basic pharmaceutical products and pharmaceutical preparation	2	x	x
Rubber and plastics products	49	x	x
Other non-metallic mineral products	7	x	x
Fabricated metal products, except machinery and equipment	43	x	x
Computer, electronic and optical products	23	x	x
Electrical equipment	16	x	x
Machinery equipment	19	x	x
Motor vehicles, trailers and semi-trailers	5		x
Other transport equipment	6		x
Furniture	19	x	x
Other manufacturing	59	x	x
Others	46		

Note: This categorization is based on a typical position of industries in the supply chain.

Table 7. Probit regression for the effect of global value chain on RoHS compliance

Variables	(1)	(2)	(3)	(4)
Export	0.356**	0.422*	0.346**	0.412*
	(0.172)	(0.220)	(0.171)	(0.220)
Global value chain	0.786***	0.912***	0.856***	0.983***
	(0.162)	(0.322)	(0.178)	(0.332)
Global value chain * Export		-0.168		-0.168
		(0.363)		(0.361)
Global value chain * Upstream			-0.314	-0.314
			(0.386)	(0.385)
Malaysia	0.618***	0.613***	0.617***	0.612***
	(0.192)	(0.193)	(0.191)	(0.193)
Constant	-2.074***	-2.110***	-2.076***	-2.113***
	(0.353)	(0.374)	(0.354)	(0.375)
Observations	467	467	467	467
Pseudo R-squared	0.234	0.235	0.236	0.236

Robust standard errors are in parentheses *** p<0.01, ** p<0.05, * p<0.1.

Table 8. Probit regression for the effect of global value chain on REACH compliance

	(1)	(2)	(3)	(4)
Variables	Full sample			
Export	0.612***	0.622***	0.615***	0.624***
	(0.201)	(0.240)	(0.201)	(0.240)
Global value chain	0.778***	0.797**	0.758***	0.774**
	(0.172)	(0.375)	(0.184)	(0.375)
Global value chain * Export		-0.0240		-0.0215
		(0.407)		(0.407)
Global value chain * Upstream			0.104	0.103
			(0.430)	(0.429)
Malaysia	0.437**	0.436**	0.438**	0.437**
	(0.203)	(0.203)	(0.203)	(0.203)
Constant	-2.394***	-2.400***	-2.397***	-2.403***
	(0.457)	(0.483)	(0.459)	(0.485)
Observations	449	449	449	449
Pseudo R-squared	0.222	0.222	0.223	0.223

Robust standard errors are in parentheses *** p<0.01, ** p<0.05, * p<0.1.